Udder morphology and milk yield of Tsigai sheep

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Abstract

This study aimed to determine how udder structure and milkability in Tsigai and crossbred Tsigai x Lacaune dairy sheep are impacted by breed and the progression of lactations. The measurements were analysed from 382 to 391 ewes during their first through third lactations, taken at two milk testing periods in varying stages of lactation. Udder morphology was evaluated through linear dimensions and ultrasound imaging, capturing elements such as udder depth, teat placement, cisternal proportions, and attachment quality. Milk yield dynamics were examined using flow meters that recorded milk letdown every 10 seconds to determine machine milk yield, machine-stripped milk, and total milk yield. The results revealed significant variances in udder size and cisternal depth between breeds, with crossbred ewes having larger udders and higher milk yields than pure Tsigai ewes. Furthermore, udder morphology deteriorated as lactation order increased, with teats becoming more horizontal and teat length expanding. Cisternal depth displayed the greatest variability among linear traits, correlating with differences in milking efficiency. Statistical tests confirmed that older ewes had more ample cisterns, thereby supporting the hypothesis that parity influences udder conformation and milkability. In conclusion, these findings provide insight into the breed-specific and lactation-related factors affecting milk production, underlining the importance of udder structure traits for optimizing dairy sheep selection and management strategies.

Keywords: dairy sheep; Lacaune; milkability; tsigai; udder; ultrasonography

Introduction

Farming dairy sheep is a traditional practice in many parts of the world (Inal et al. 2021; Djimon et al., 2024) including Slovakia, where the predominant breeds are Tsigai, Improved Valachian, Lacaune and East Friesian. The Lacaune sheep is the major breed originating from France and has subsequently been genetically improved over the past 50 years for increased milk production potential. The dairy sheep industry in Slovakia is expanding rapidly.

Over the past 30 years, there has been an increased interest in studying udder morphology in sheep regarding the suitability of the udder for machine milking, particularly in undeveloped countries where dairy sheep have a major economic and social impact. Mammary morphology has already been described as an important factor in the machine milkability of dairy ewes (Márta et al. 2024). Milking techniques are crucial to adapt dairy ewes as best as possible to the milking environment. Sheep with well-attached udders and less cranially orientated teats were less likely to experience udder inflammation than ewes with deep udders and forward-facing teats.

Mammary morphology-related traits are the most critical functional traits in dairy sheep due to their relationship with machine milking aptitude, their influence on udder pathology, mainly mastitis, and the animal's welfare. Several factors influence milk production in sheep, including their genetic background, age and parity, nutrition, body condition, stage of lactation, the number of lambs they give birth to, how their lambs are weaned and when; the frequency at which they are milked; their level of activity; and the effects of the environment they are in.

Many factors influence ewe milk production, including breed, nutrition, environment, and behaviour, including activity levels (Tóth et al. 2017; Libis-Márta et al. 2021). Milk removal from the udder is a determining factor that stimulates milk secretion; consequently, milk removal enhances milk yield (Bruckmaier and Blum, 1996).

Recent studies describing udder morphology reported that some udder morphometric measurements impact milk yield. The decrease in milk production throughout lactation caused modifications in udder traits due to the reduction of udder secretory tissue and secretion rate (Wilde et al. 1996).

The decrease in milk production through lactation also modified morphological traits. Teats and udder measurements decreased dramatically in late lactation.

Cisternal size and cisternal milk fraction affect milk secretion rate and ejection kinetics. Animals with larger cisterns are considered more efficient milk producers and more tolerant to longer milking intervals and need simpler milking routines – they tend to lose less milk yield when milking frequency is reduced and cope better with extended intervals between milkings (Stelwagen, 2001).

Milk ejection is an innate reflex that the animal cannot control. It is a response to tactile stimulation of the udder as a neuroendocrine reflex and releases oxytocin from the pituitary (Bruckmaier and Blum, 1998; Bruckmaier, 2001). On the other hand, in dairy cows milk ejection causes a sudden pressure increase within the teat cistern (Mayer et al., 1991) and an enlargement of the cisterns measured by ultrasonography (Bruckmaier and Blum, 1992).

The milk yield depends on many things, for instance, milking frequency and degree of udder emptying, stage of lactation (Bruckmaier and Hilger, 2001; Bach and Busto, 2005), time since last milking (Stelwagen et al. 1997; Bruckmaier and Hilger, 2001; Friggens and Rasmussen, 2001), breed and nutrition. If there is an incomplete emptying of the udder, through suboptimal milking technique, failure to attach the teat cups or lack of milk ejection, affects the milk yield negatively (Bach and Busto, 2005). It is also commonly known that the milk yield will decrease with higher days in milk (DIM) (Bruckmaier and Hilger, 2001). At the start of lactation, the milk yield rapidly increases until peak lactation, after which it will decrease.

The rate of milk secretion and the process of milk removal are influenced by the size of the cistern (Wilde and Knight, 1990; Wilde et al. 1996; Stelwagen, 2001. In sheep and cattle, it is established that animals with large cisterns are better milk producers and are adapted to simple milking routines and longer milking intervals (Labussiere, 1988). It is also reported that animals with small cisterns are more susceptible to the short-term autocrine inhibition of milk secretion in the mammary gland and are reported to respond better to more frequent milking (Wilde et al., 1996, Stelwagen et al., 1998).

This study aimed to evaluate the effect of breed and lactation order on udder morphology and milkability traits in dairy sheep Tsigai (T) and Tsigai × Lacaune (TxLC) crossbred, using linear and ultrasound measurements and detailed milk yield analysis.

Material and Methods

Functional and morphological characteristics of the sheep udder were evaluated in a selected population of sheep (in one experimental flock of dairy sheep; Trencianska Tepla). The statistics methods describing the udder morphology of purebred T and TxLC crossbred ewes were calculated from cumulative udder measurement data collected during two control milkings. Tsigai ewes generally exhibit a lactation length of around 120 to 150 days, influenced by intrinsic factors (like genetics and parity) and extrinsic factors (such as feeding practices and environmental conditions).

The measurements were planned and performed while maintaining scientific accuracy, striving not to overload the animals with unnecessary stress. The timing was selected to represent changes occurring during lactation and during the day. Machine stripping was used for post-milking milk collection, performed automatically by continuing the vacuum until milk flow ceased; manual stripping was not applied. There were 382-391 measurements depending on the trait of interest. Only clinically healthy females without any signs of mastitis were included in the study. The average age of the animals enrolled in the experiment was 3.3 years.

The experiment included ewes in their 1st to 3rd lactation. During the milking period, 2 milk control measurements (MCM) were conducted, where MCM is defined as an evening milking followed by a morning milking. The first MCM was performed when the ewes were on average on day 124 of lactation, and the second MCM was conducted when the ewes were on average on day 157. At the MCM, flow meters were installed to detect milk let-down (milk yield) at 10-second intervals, allowing us to determine the amount of milk milked in 60 seconds (MY60s), the total amount of milk milked by machine (machine milk yield – MMY), and the amount of milk obtained by machine stripping (MS). The text describes the amount of milk obtained through machine milking and stripping, including the total milk yield (TMY), the proportion of machine milk yield to total milk yield (MMY/TMY), and the proportion of milk (from TMY) milked in 30 and 60 seconds (MY30s and MY60s, respectively). It is noted that sheep were not hand-stripped after machine milking.

Udder morphology, including linear assessment, was assessed during morning milking. Ultrasonography was then used to measure udder cisternae. A 9-point scale was used for the linear description of the udder of all ewes included in the experiment. The following parameters were evaluated:

The linear assessment scheme contained 7 udder and teat traits: udder depth (1 - low, 9 - high), cistern depth 'from the bottom' the teat level (1 - none, 9 - high), teat position (1 - vertical, 9 - horizontal), teat size (1 - short, 9 - long), udder cleft (1 - not detectable, 9 - expressive), udder attachment (1 - narrow, 9 - wide), udder shape (1 - bad, 9 - ideal). Statistical analysis was formulated using the restricted maximum likelihood (REML) methodology (MIXED) procedure implemented in SAS/STAT v.9.2.

External udder measurements of six traits (Milerski et al. 2006) were made by at least two technicians using a ruler, measuring tape, and protractor. They included udder length (UL), udder width (UW), rear udder depth (RUD), cistern depth (CD), teat length (TL) and teat angle from the vertical (TA) (Figure 1).

Ultrasound images of the left and right udder cisterns were recorded by portable ultrasonography with a 3.5 MHz convex sector probe as previously described (Nudda et al. 2000). The procedure uses contact gel and places the probe directly against the upper part of the median suspensory ligament in the inguinal abdominal fold. The operator performed an equal axis scan of the opposite side of the udder to obtain a sonographic image with the largest cistern size ('from the side' method). Ultrasound examination was carried out using a stationary ultrasonographic device Digital Ultrasonic Imaging System, model DP-3300 VET, GmbH, Germany.

Milkability variables were measured immediately during the milking process. Following this, the udder was left to rest for 12 hours to allow it to naturally fill with milk without any interventions. After this 12-hour resting phase, ultrasound images were captured once for each half of the udder to measure linear udder dimensions and exact udder dimensions. On the sonographic pictures, the length of the left (LLC1) and right (LRC1) cisterns and the width of the left (WLC1) and right (WRC1) cisterns (in millimetres) were measured from the cross-sectional scans. By using digital technology, the left (ALC1) and right (ARC1) cistern areas (in mm^2) were measured, as well as the sum of the areas in both cisterns (SLRC1). For some control measurements, in addition to scanning the udder cisterns using the 'from the side' method, the sizes of the left and right udder cisterns were also investigated by scanning the entire ventral udder using the 'from the bottom' method. Udders were measured while immersed in water, with the probe held in the water against the udder wall as described (Bruckmaier and Blum, 1992; Bruckmaier et al. 1997). Sonographic images obtained 'from the bottom' produced equal measurements for the udder cisterns as sonography 'from the side' (LLC2, LRC2, WLC2, WRC2, ALC2, ARC2, SLRC2).

Control measurements refer to a specific set of results obtained simultaneously. These individual control measurements can be compared with each other (for instance, when monitoring changes over time). Significance levels were tested as follows: $P<0.001$ (+++); $P<0.01$ (++); $P<0.05$ (+); $P\geq0.05$ (ns – non-significant).

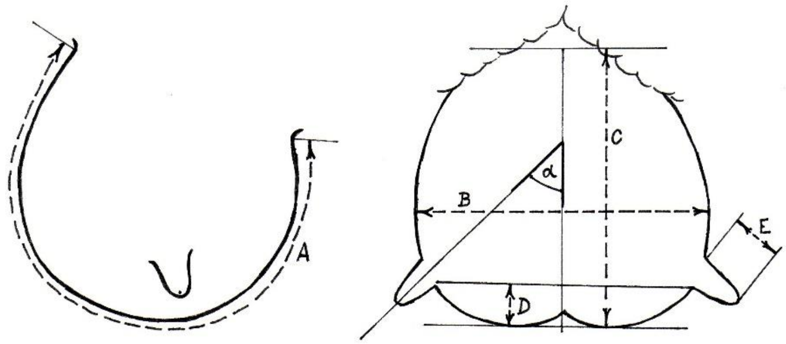

Fig 1: Morphological parameters measured on the udder and teats
A: udder length (UL); B: udder width (UW); C: rear udder depth (RUD); D: cistern depth (CD); E: teat length (TL); α: teat angle from the vertical (TA).

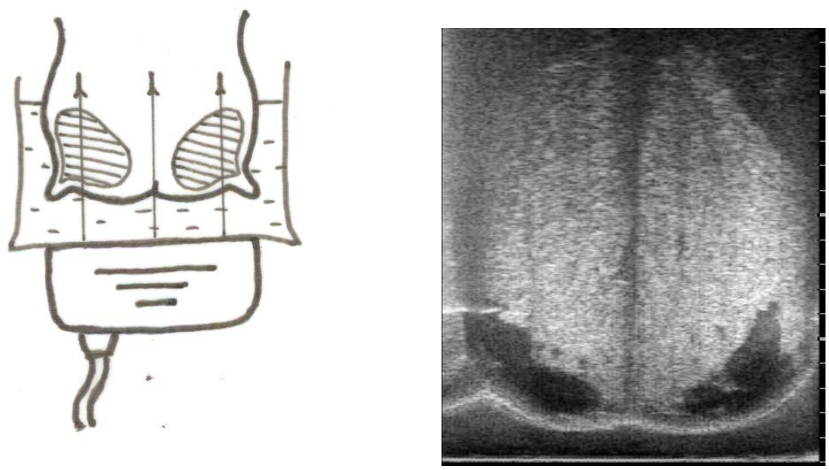

Fig 2: Ultrasonic scan of sheep udder 'from the bottom' (sum of cistern areas –BCA)

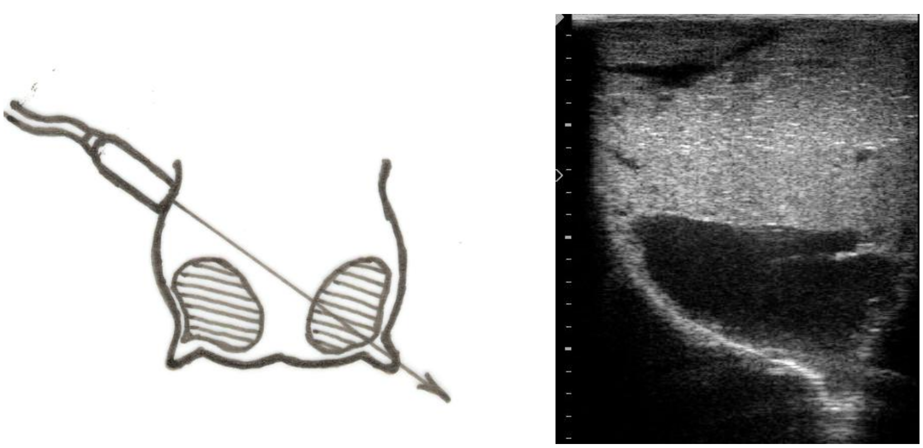

Fig 3: Ultrasonic scan of sheep udder 'from the side' (sum of both cistern areas – SCA)

Results and Discussion

Tables 1 to 5 show the basic variation statistics characterising the udder morphology of purebred Tsigai ewes and TxLC crossbred ewes, calculated based on the cumulative udder measurement data of all experimental ewes for the two control measurements. The greatest variability, assessed by the coefficient of variation, was observed for the CD (cistern depth) and TP (teat position) traits. The mean values of the individual linear measures ranged from 4.1 (CD) to 5.2 (UC – udder cleft), where 5 represents the population mean (Table 1). The fact that the CD indicator showed the greatest variability is confirmed by the variability of the HCEx indicator when the cistern height ranged from 0 to 6.5 cm (Table 2).

One task was also to compare the udder morphology of purebred ewes and crossbred ewes oriented to dairy performance, bred in Slovakia (T, TxLC). By comparing the linear measures and udder morphology of these ewes, it is evident that the purebred T ewes from breeding 1 had the smallest udders based on the assessment of UD (udder depth), UL (udder length), UW (udder width). The purebred T ewes from breeding 2 had larger udders, and the TxLC crosses from breeding 1 had the largest udders based on the assessment of the same measures (Tables 1 and 2). For example, UL for T ewes (breeding 1) was 18.17 cm and from breeding 2, 20.62 cm, for CxLC crosses (breeding 1) 22.62 cm; similarly, UW 10.00 cm and 11.29 cm, TxLC 11.56 cm. On the other hand, T ewes had the best teat length, with cistern height indicators of 38.76 and 36.67 mm for purebred T ewes; and 50.71 mm for TxLC crosses (Table 2). According to the linear evaluation, the best teat position was the TxLC crossbred ewes from the farm Trencianska Tepla.

The indicators CD and HCEx indicate that the Tsigai ewes from both farms had the smallest udder cisterns, judged based on linear evaluation and the exact position of the teats detected through the protractor. TxLC crossbreds had the largest cisterns. As detected by linear evaluation, udder cleft was greatest in purebred T ewes from breeding 2, with an average value of 5.55 and further in TxLC crossbred ewes (breeding 1) with a value of 5.12. The lowest value was in purebred T ewes from breeding 1 (Table 1).

The data in Tables 1 and 2 indicate a tendency toward decreasing udder size (UD, UL, UW), a shift toward a more horizontal teat position, and increasing teat size between the two measurement points. However, due to the limited number of measurements, these findings should be interpreted with caution and cannot be conclusively attributed to progression during lactation.

The genotypic composition of the experimental ewes in both breeds (breeding 1 and breeding 2) was the same, except TxLC crossbred ewes were also observed in breeding 1. In purebred T ewes, the factor 'genotype' had a statistically significant effect on the observed linear values; differences were found for all linear and morphological measures, with a very high impact ($P<0.001$) for most of them – except for teat size and udder attachment ($P<0.01$). Differences were also observed in T crosses with the Lacaune breed. If the values of CD and HCEx were greater, as a rule, the values of TP and UA were also higher, i.e. ewes with larger teats had a more horizontal teat position.

The basic variation-statistic characteristics of the observed parameters of the left and right udder cisterns of sheep detected using the sonograph method 'from the bottom' and 'from the side' are presented in Tables 3 and 4. These are cumulative data for all experimental ewes. The basic variation statistics were calculated from the measures of 385 udder cisterns detected by the 'from the bottom' method and 385 measures of udder cisterns detected by the 'from the side' method. From the data presented in Tables 3 and 4, it is clear that the udder cistern measures detected by the 'from the bottom' method are, in all cases, smaller than those detected by the 'from the side' method. For example, the length of the left udder cistern 'from the bottom' (LLC1) was 58.6 mm, the same measure found by the 'from the side' method (LLC2): 69.8 mm. The sum of the left and right cisterns detected by the 'from the bottom' method (SLRC1) was 2789.0 mm^2; for the 'from the side' method, it was 3462.8 mm^2. On the contrary, the coefficients of variation of almost all parameters detected by the 'from the bottom' method were smaller than those of the 'from the side' method. The size of the right udder cistern was slightly larger than that of the left cistern, irrespective of the detection method.

From the data presented in Tables 3 and 4, it is evident that both left and right udder cisterns were smallest, irrespective of the detection method, in purebred T ewes from breeding 1 and 2, like in TxLC crosses. The area of the left udder cistern detected by the 'from the bottom' method in the TxLC crossbred ewes was approximately 1.5 times larger than that of the purebred T ewes from breeding 1 (1339.88 mm^2 and 1251.87 mm^2, respectively).

Table 3 also shows that the factor parity (lactation order) had a statistically significant effect ($P<0.01$ and $P<0.05$, respectively) on the observed left and right udder cistern measures in several cases. The expected assumption that older ewes generally have larger udder cisterns was confirmed. Although some differences between ewes at 1st, 2nd and 3rd lactation were not statistically significant, most of the parameters observed a tendency of increasing udder cisterns with age (Tables 3 and 4).

Table 5 shows the basic statistical data characterizing the milk yield of all experimental ewes concerning herd and genotype, lactation year, lactation order and control measurements. Several interesting and largely surprising results

Table 1: Linear evaluation of the udder of ewes depending on the breed group

Source of variance	Measurement						
	Udder depth (UD)[cm]	**Cistern depth (CD) [cm]**	**Teat position (TP)**	**Teat size (TS)**	**Udder cleft (UC)**	**Udder attachment (UA)**	**Udder shape (US)**
No of control measurements	391	391	391	391	391	391	391
Total average	4.4	4.1	4.5	4.5	5.2	5.1	4.9
SD	1.08	1.64	1.39	1.20	1.27	1.11	1.33
Coefficient of variation	24.76	39.99	30.63	26.52	24.45	21.61	27.09
Minimum	1	1	1	2	1	3	2
Maximum	7	9	9	9	9	8	8
Genotype							
1 * T	3.61a	3.95a	4.34a	4.25a	4.69a	4.89a	4.14a
1 * TxLC	4.91bc	5.93b	5.91b	4.40a	5.12b	5.44bc	5.56bc
2 * T	4.66c	3.57c	4.16a	4.74b	5.55c	5.21c	5.17c
F test value	46.31+++	39.38++	32.17+++	5.48++	15.07+++	5.94++	32.99+++
Control year							
2023	4.39	4.47	4.84	4.40	4.96	5.07	4.89
2024	4.39	4.50	4.77	4.52	5.29	5.30	5.03
F test value	0.00ns	0.04ns	0.26ns	0.85ns	5.96+	3.82ns	0.88ns
Parity							
1st	4.09a	4.08a	4.47a	4.37	5.03	5.13	4.70a
2nd	4.38b	4.64bc	4.95bc	4.41	5.06	5.16	4.99ab
3rd	4.70c	4.73c	5.00c	4.61	5.28	5.26	5.19b
F test value	10.32+++	5.99++	5.60++	1.46ns	1.47ns	0.47ns	4.63+
Milking control measurement							
1st	4.43	4.20	4.44	4.53	5.24	5.10	4.86
2nd	4.35	4.77	5.17	4.39	5.00	5.27	5.06
F test value	0.07ns	1.68ns	3.71ns	0.20ns	0.49ns	0.33ns	0.33ns
Covariance							
Days in milk (F value)	0.36ns	1.63ns	3.21ns	0.05ns	0.00ns	3.83ns	3.64ns

T – Tsigai; TxLC – Tsigai x Lacaune crossbreed; +++ P<0.001; ++ P<0.01; + P<0.05; ns – non significant (non-significant effect); a, b – differences in means marked with an unequal letter are statistically significant.

Table 2: Exact udder measurements of ewes (using tape measure and protractor) depending on breed group

Source of variance	Measurements					
	UL [cm]	**UW [cm]**	**RUD [mm]**	**HCEx [mm]**	**TL [cm]**	**TA[°]**
No of control measurements	393	393	393	382	393	393
Total average	20.1	10.9	13.8	39.5	3.7	1.5
SD	3.2	1.3	1.9	10.5	0.7	1.1
Coefficient of variation	16.17	11.78	14.01	26.49	18.01	72.57
Minimum	8	8	9	0	2	4
Maximum	32	16	26	6.5	7	88
Genotype						
1 * T	18.17a	10.00a	12.39a	38.76a	3.52a	1.25a
1 * TxLC	22.62b	11.56bc	14.83bc	50.71b	3.45a	2.78b
2 * T	20.62c	11.29c	14.27c	36.67a	3.82b	1.25a
F test value	42.85+++	48.25+++	48.81+++	33.34+++	8.61+++	44.15+++
Control year						
2023	20.09	11.25	14.19	42.77	3.41	1.46
2024	20.69	10.64	13.47	41.33	3.78	2.05
F test value	3.02ns	19.81+++	12.18+++	1.58ns	27.53+++	25.85+++
Parity						
1st	19.69a	10.60a	13.36a	39.55a	3.58	1.53a
2nd	20.41ab	11.05bc	13.71a	43.83bc	3.55	1.81ab
3rd	21.08b	11.19c	14.42b	42.76c	3.66	1.93b
F test value	6.03++	7.71+++	10.26+++	5.42++	1.05ns	4.56+
Milking control measurement						
1st	20.35	10.60	13.83	37.59	3.68	1.61
2nd	20.44	11.30	13.83	46.51	3.51	1.90
F test value	0.01ns	4.08+	0.00ns	9.77++	0.93ns	0.93ns
Covariance						
Days in milk (F value)	4.16+	8.27++	0.27ns	3.31ns	0.00ns	4.90+

T – Tsigai; TxLC – Tsigai x Lacaune crossbreed; +++ P<0.001; ++ P<0.01; + P<0.05; ns – non significant (non-significant effect); a. b – differences in means marked with an unequal letter are statistically significant. UL- **Udder length; UW- Udder width; RUD- Rear udder depth; Cistern height- HCEx; TL- Teat length; TA- Teat angle**

Table 3: Measurements of the left and right udder cisterns of ewes detected by the 'from the bottom' method,

Source of variance	Measurement						
	LLC1 [mm]	**WLC1[mm]**	**ALC1[mm²]**	**LRC1 [mm]**	**(WRC1) [mm]**	**ARC1 mm2**	**(SLRC2) [mm²]**
No of control measurements	385	385	385	385	385	385	385
Total average	58.6	31.9	1390.6	59.1	33.0	1398.4	2789.0
SD	9.48	6.82	457.11	10.32	6.82	466.48	891.10
Coefficient of variation	16.20	21.37	32.87	17.45	20.69	33.36	31.95
Minimum	30	13	329	30	14	242	667
Maximum	96	54	3082	91	55	3252	6281
Genotype							
1 * T	57.38a	29.58a	1251.87a	57.60a	30.44a	1241.48a	2493.35a
1 * TxLC	67.78b	34.92b	1788.83b	67.64b	36.52b	1778.07b	3566.89b
2 * T	55.99a	32.33c	1339.88a	57.11a	33.42c	1368.69c	2708.51a
F test value	30.14+++	13.82+++	27.80+++	21.79+++	17.51+++	26.34+++	29.00+++
Control year							
2023	61.53	32.81	1468.38	60.80	32.66	1415.78	2884.11
2024	59.24	31.75	1452.00	60.76	34.26	1509.72	2961.73
F test value	5.04+	2.07ns	0.11ns	0.00ns	4.77+	3.50ns	0.65ns
Parity							
1st	59.06	30.76a	1353.67a	59.73	31.74a	1371.35a	2725.02a
2nd	61.00	32.26a	1490.9bc	61.56	34.04bc	1498.9bc	2989.9bc
3rd	61.10	33.81b	1535.92c	61.05	34.60c	1517.96c	3053.86c
F test value	1.84ns	6.41++	5.48++	1.00ns	6.23++	3.67+	4.84++
Milking control measurement							
1st	60.58	30.78	1421.56	60.49	32.10	1447.79	2869.29
2nd	60.19	33.77	1498.83	61.08	34.82	1477.70	2976.54
F test value	0.02ns	2.57ns	0.38ns	0.04ns	2.12ns	0.06ns	0.19ns
Covariance							
Days in milk (F value)	1.85ns	8.72++	5.95+	3.03ns	6.73++	4.30+	5.46+

T – Tsigai; TxLC – Tsigai x Lacaune crossbreed; +++ P<0.001; ++ P<0.01; + P<0.05; ns – non significant (non-significant effect); a. b – differences in means marked with an unequal letter are statistically significant. LLC1- Length of left cistern; WLCl- Width of left cistern; ALCl- Area of left cistern; LRCl- Length of right cistern; WRCl- Width of right cistern; ARCl- Area of right cistern; SRC2- Sums of both crosssection areas

Table 4: Measurements of the left and right udder cistern of ewes detected by the 'from the side' method

Source of variance	Measurement						
	LLC2 [mm]	WLC2 [mm]	ALC2 [mm²]	LRC2 [mm]	WRC2 [mm]	ARC2 [mm²]	SLRC2 [mm²]
No of control measurements	385	385	385	385	385	385	385
Total average	69.8	32.6	1693.6	69.7	33.4	1769.2	3462.8
SD	9.18	6.38	482.04	9.48	6.83	545.11	962.84
Coefficient of variation	13.16	19.58	28.46	13.60	20.43	30.81	27.81
Minimum	37	17	498	37	13	391	966
Maximum	100	59	3864	106	54	3822	7474
Genotype							
1 * T	66.79a	29.77a	1481.58a	66.30a	30.18a	1512.86a	2994.38a
1 * TxLC	76.92b	33.72bc	1885.3bc	77.14b	32.76b	1922.6bc	3807.8bc
2 * T	69.23c	34.16c	1775.38c	69.29c	35.97c	1894.83c	3670.17c
F test value	24.50+++	17.79+++	19.81+++	26.35+++	23.11+++	20.73+++	22.93+++
Control year							
2023	71.19	32.42	1683.28	71.36	32.12	1683.47	3366.66
2024	70.76	32.68	1744.89	70.46	33.82	1870.03	3614.91
F test value	0.19ns	0.14ns	1.41ns	0.77ns	5.32+	10.13++	5.75+
Parity							
1st	69.60	32.03	1671.99	69.96	33.00	1755.25	3427.17
2nd	71.59	32.67	1745.20	71.56	32.84	1796.26	3541.42
3rd	71.74	32.96	1725.08	71.21	33.07	1778.72	3503.77
F test value	2.12ns	0.71ns	0.74ns	0.96ns	0.03ns	0.17ns	0.43ns
Milking control measurement							
1st	70.35	30.00	1537.90	71.37	30.21	1627.28	3165.19
2nd	71.61	35.10	1890.28	70.45	35.73	1626.21	3816.38
F test value	0.26ns	8.69++	7.26++	0.13ns	8.87++	4.08+	6.21+
Covariance							
Days in milk (F value)	6.20+	20.68+++	20.51+++	2.60ns	24.43+++	16.80+++	21.05+++

T – Tsigai; TxLC – Tsigai x Lacaune crossbreed; +++ P<0.001; ++ P<0.01; + P<0.05; ns – non significant (non-significant effect); a. b – differences in means marked with an unequal letter are statistically significant. LLC2- Length of left cistern; WLC2- Width of left cistern; ALC2- Area of left cistern; 2- Length of right cistern; WRC2- Width of right cistern; ARC2- Area of right cistern; SLRC2- Sums of both crosssection areas

Table 5: Indicators characterising the milk yield of ewes depending on breed group

Source of variance	Measurement						
	MY60s [ml]	MMY [ml]	MS [ml]	TMY [ml]	MSR	MYR30s	MYR60s
Number of control measurements	387	387	386	386	386	386	386
Total average	250.9	256.6	110.1	366.4	30.9	58.1	68.1
SD	106.42	111.67	56.85	123.75	14.40	16.72	15.05
Coefficient of variation	42.42	43.53	51.65	33.77	46.60	28.77	22.10
Minimum	0	10	20	30	4.35	0	0
Maximum	700	720	380	880	83.33	94.12	95.65
Genotype							
1 * T	191.71a	194.21a	72.78a	266.94a	27.23a	64.80a	72.19a
1 * TxLC	274.95bc	286.03bc	94.87b	380.85b	26.78a	59.51b	71.61a
2 * T	281.69c	287.47c	142.94c	430.16c	35.30b	52.95c	63.50b
F value	27.38+++	27.77+++	48.74+++	59.01+++	11.47+++	16.04+++	11.43+++
Control year							
2023	268.09	277.95	107.20	384.99	29.33	56.60	68.93
2024	230.80	233.85	99.86	333.65	30.22	61.57	69.27
F value	10.32++	13.49+++	1.44ns	14.87+++	0.33ns	7.64++	0.04ns
Parity							
1st	258.26	269.70	104.91	374.58	28.07	59.18	70.26
2nd	243.69	248.30	104.58	352.59	30.85	59.39	67.89
3rd	246.40	249.70	101.10	350.78	30.40	58.69	69.15
F value	0.65ns	1.44ns	0.17ns	1.45ns	1.33ns	0.06ns	0.72ns
Milking control measurement							
1st	249.89	253.82	81.75	335.43	25.97	60.96	73.04
2nd	249.01	257.98	125.31	383.20	33.57	57.21	65.16
F value	0.00ns	0.02ns	7.98++	2.03ns	3.78ns	0.68ns	3.72ns
Covariance							
Days in milk (F value)	1.47ns	2.79ns	18.72+++	12.19+++	3.19ns	2.29ns	4.46+

T – Tsigai; TxLC – Tsigai x Lacaune crossbreed; +++ P<0.001; ++ P<0.01; + P<0.05; ns – non significant (non-significant effect); a. b – differences in means marked with an unequal letter are statistically significant. MY60- Milk yield in 60s; MMY- Machine-milked yield; MS- Machine-stripped milk; TMY- Total milk yield; MSR- Machine stripping ratio; MYR30- Milk yield ratio in 30s; MYR60- Milk yield ratio in 60s

emerge from that table based on 387 control measurements. For both breeds, machine milk yield averaged 256.6 ml, with a range of 10 to 720 ml, and total milk yield averaged 366.4 ml, with a range of 30 to 880 ml. This shows that the total daily yield of the best ewes exceeded 1.5 litres. We also found large ranges in the indicators for the proportion of machine milking and the proportion of milk milked in 30 and 60 seconds. The proportion of machine stripping ratio was relatively high (30.9%) in the study population, with a range of 4.35 to 83.33%. On average, the experimental ewes milked 58.1% of the milk in 30 seconds and 68.1% of the total milk in 60 seconds. Some of the studied ewes did not start milking even at 60 sec; on the contrary, in the best ewe, the proportion of milk milked at 60 sec from TMY was up to 95.65%.

Milk yield in dairy sheep is positively correlated (0.4 - 0.71) with udder and teat traits in Manchega and Tsigai dairy sheep, respectively (Labussiere, 1988). Moreover, increased milk yield was associated with udder width, udder height and udder circumference. Older ewes' decrease in milk yield rate during lactation is higher than that of younger ewes (Ruiz et al. 2000). Milk yield decreases as lactation progresses after peaking in the first few weeks of lactation, while fat and protein content also increase (Ploumi et al. 1998).

However, the decline in milk yield was more pronounced than the increase in fat and protein content. In cases where slight differences in milk yield are observed between stages of lactation, the feeding level is likely the cause (Oravcová et al. 2006). Milk yield in mid- and late lactation is affected by the milk yield in early lactation; higher milk yields in the first month increase the milk yield throughout the rest of lactation and prolong the lactation period (Jordan, 1998). Within the first 30 days of lactation, approximately 25% of the total milk yield is produced (McKusick et al. 2001). During lactation, mammary secretory cells gradually get smaller and less active via involution.

Conclusion

Our results indicate that improving the native Tsigai breed with Lacaune genetics can lead to an increase in udder size and milk production in crossbred ewes. However, this genetic improvement is associated with a deterioration in teat position due to the enlargement of the udder cisterns, which may negatively affect milkability. Traits related to milkability (machine stripping ratio, milk yield ratio in 30 and 60 seconds) showed slightly lower values in crossbreds compared to purebred Tsigai ewes, with the least favourable values observed in purebred Lacaune ewes.

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